

CLAIMS

What is claimed is:

1. A method for determining an axial force acting on each one of a  
5 plurality of roller cones on a roller cone drill bit during drilling, comprising:  
calculating, from a geometry of cutting elements on each of the roller cones  
and an earth formation being drilled by the drill bit, an axial force acting on each of  
the cutting elements;  
incrementally rotating the bit and recalculating the axial forces acting on each  
10 of the cutting elements;  
repeating the incrementally rotating and recalculating for a selected number of  
incremental rotations; and  
combining the axial force acting on the cutting elements on each one of the  
roller cones.  
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2. The method as defined in Claim 1 wherein the axial force acting on  
each of the cutting elements totals an axial force applied to the drill bit.
3. The method of Claim 2 further comprising determining an axial force  
20 acting on each of the cutting elements with respect to a predetermined relationship  
between depth of penetration and axial force applied for the cutting element geometry  
and the earth formation.
4. The method of Claim 3 wherein the predetermined relationship is  
25 determined by laboratory experiment.

5. A method for determining a volume of formation cut by each one of a plurality of roller cones on a drill bit drilling in earth formations, comprising:

selecting bit design parameters, comprising at least a geometry of a cutting element on the drill bit;

5 selecting an earth formation;

calculating from the selected bit design parameters and the selected earth formation, parameters for a crater formed when each one of a plurality of cutting elements on each of the roller cones contacts the earth formation, the parameters including at least a volume of the crater;

10 incrementally rotating the bit, and repeating the calculating of the crater parameters for a selected number of incremental rotations; and

combining the volume of each crater formed by each of the cutting elements on each of the roller cones to determine the volume of formation cut by each of the roller cones.

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6. The method as defined in Claim 5 wherein the volume of each of the craters is determined by:

determining an axial force on each of the cutting elements;

20 calculating, from the axial force on each of the cutting elements, an expected depth of penetration and projected area of contact between each of the cutting elements and the earth formation; and

calculating the volume of each of the craters from the expected depth of penetration and projected area of contact.

25 7. The method as defined in Claim 6 further wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

8. The method of Claim 7 further comprising determining an axial force acting on each of the cutting elements with respect to a predetermined relationship  
30 between depth of penetration and axial force applied for the cutting element geometry and the earth formation.

9. The method of Claim 8 wherein the predetermined relationship is determined by laboratory experiment.

10. A method for balancing axial forces acting on each one of a plurality of roller cones on a roller cone drill bit during drilling, comprising:

calculating, from a geometry of cutting elements on each of the roller cones and an earth formation being drilled by the drill bit, an axial force acting on each of the cutting elements;

incrementally rotating the bit and recalculating the axial forces acting on each of the cutting elements;

repeating the incrementally rotating and recalculating for a selected number of incremental rotations;

combining the axial force acting on the cutting elements on each one of the roller cones; and

adjusting at least one bit design parameter, and repeating the calculating the axial force, incrementally rotating and combining the axial force, until a difference between the combined axial force on each one of the roller cones is less than a difference between the combined axial force determined prior to adjusting the at least one initial design parameter.

11. The method as defined in Claim 10 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

12. The method of Claim 11 further comprising determining an axial force acting on each of the cutting elements with respect to a predetermined relationship between depth of penetration and axial force applied for the cutting element geometry and the earth formation.

13. The method of Claim 12 wherein the predetermined relationship is determined by laboratory experiment.

14. The method as defined in Claim 10 wherein the at least one bit design parameter comprises a number of cutting elements on at least one of the cones.

15. The method as defined in Claim 10 wherein the at least one bit design parameter comprises a location of cutting elements on at least one of the cones.

16. A method for balancing a volume of formation cut by each one of a plurality of roller cones on a drill bit drilling in earth formations, comprising:

selecting bit design parameters, comprising at least a geometry of a cutting element on the drill bit;

5 selecting an earth formation;

calculating from the selected bit design parameters and the selected earth formation, parameters for a crater formed when each one of a plurality of cutting elements on each of the roller cones contacts the earth formation, the parameters including at least a volume of the crater;

10 incrementally rotating the bit, and repeating the calculating of the crater parameters for a selected number of incremental rotations;

combining the volume of each crater formed by each of the cutting elements on each of the roller cones to determine the volume of formation cut by each of the roller cones; and

15 adjusting at least one of the bit design parameters, and repeating the calculating the crater volume, incrementally rotating and combining the volume until a difference between the combined volume cut by each of the cones is less than the combined volume determined prior to the adjusting the at least one of the bit design parameters.

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17. The method as defined in Claim 16 wherein the volume of each of the craters is determined by:

determining an axial force on each of the cutting elements;

25 calculating, from the axial force on each of the cutting elements, an expected depth of penetration and projected area of contact between each of the cutting elements and the earth formation; and

calculating the volume of each of the craters from the expected depth of penetration and projected area of contact.

30 18. The method as defined in Claim 17 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.

19. The method of Claim 18 further comprising determining an axial force acting on each of the cutting elements with respect to a predetermined relationship between depth of penetration and axial force applied for the cutting element geometry and the earth formation.

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20. The method as defined in Claim 16 wherein the at least one bit design parameter comprises a number of cutting elements on at least one of the cones.

21. The method as defined in Claim 16 wherein the at least one bit design  
10 parameter comprises a location of cutting elements on at least one of the cones.

22. A method for optimizing a design of a roller cone drill bit, comprising:  
simulating the bit drilling through a selected earth formation;  
adjusting at least one design parameter of the bit;  
repeating the simulating the bit drilling; and  
5 repeating the adjusting and simulating until an optimized design is determined.

23. The method as defined in Claim 22 wherein the at least one design  
parameter comprises a parameter selected from the group of a number of cutting  
elements on each one of a plurality of roller cones, cutting element type, and a number  
10 of rows of cutting elements on each one of the plurality of roller cones.

24. The method as defined in Claim 22 wherein the optimized design is  
determined when a rate of penetration of the bit through the selected earth formation  
is maximized.

15 25. The method as defined in Claim 22 wherein the optimized design is  
determined when axial force on the bit is substantially balanced between the roller  
cones.

20 26. The method as defined in Claim 22 wherein the optimized design is  
determined when a volume of formation cut by the bit is substantially balanced  
between the roller cones.

25 27. The method as defined in Claim 22 wherein the simulating comprises:  
selecting bit design parameters;  
selecting drilling parameters;  
selecting an earth formation to be represented as drilled;  
calculating from the selected parameters and the formation, parameters for a  
crater formed when one of a plurality of cutting elements on the bit contacts the earth  
30 formation, the cutting elements having known geometry;  
calculating a bottomhole geometry, wherein the crater is removed from a  
bottomhole surface;



incrementally rotating the bit;

repeating the calculating of the crater parameters and the bottomhole geometry based on calculated roller cone rotation speed and geometrical location with respect to rotation of the bit about its axis.

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28. The method of Claim 27 wherein the predetermined relationship is determined by laboratory experiment.